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UTILIZATION OF DOLOMITE AND HIGH-MAGNESIUM LIMESTONE

BY

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By Paul Hatmaker[2]

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INTRODUCTION

This paper covers briefly the particular field of dolomite and magnesium limestone; certain uses of high-calcium limestone are mentioned only to show more clearly the limitations of the magnesian rocks. Such a comparison is helpful because magnesium carbonate is essential for some uses; for others it is immaterial; and for many its presence in an appreciable amount is objectionable.

Magnesium carbonate, occurring as a rock resembling limestone or dolomite, is described in United States Bureau of Mines Information Circular 6437, Magnesite. Other compounds of magnesium are described in United States Bureau of Mines Information Circular 6406, Magnesium Compounds (Other Than Magnesite).

Limestone, geologically, is a rock composed essentially of calcium carbonate; commercially, however, the term may include dolomite and magnesium limestone.

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S Bureau of Mines Information Circular 6524."

2 Mining engineer, building materials section, U. S. Bureau of Mines.

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Dolomite is a distinct mineral composed of calcium and magnesium carbonates combined in molecular proportions as expressed by the formula $CaMg(CO_3)_2$. Dolomitic limestones are those which, though containing considerable dolomite, include in addition either calcium carbonate or a physical mixture (not a chemical combination) of calcium and magnesium carbonates. Ordinarily the term "limestone" means a rock containing less than 10 per cent of magnesium carbonate. With more than 10 per cent of magnesium carbonate the term "magnesium limestone" is used until the amount is about 40 to 45 per cent, when such rock is called "dolomite." The term "high-calcium limestone" commonly means one containing at least 95 per cent of calcium carbonate and not more than 5 per cent of magnesium carbonate. "Low-magnesium limestone" applies in a general way to rocks in which the magnesium carbonate content is between 10 and 20 per cent; with more than 20 per cent magnesium carbonate the term "high-magnesium limestone" may be employed. Many rocks containing a high percentage of magnesium carbonate are not true dolomites, but dolomitic or high-magnesium limestones. They are, however, commonly known as dolomite. No very definite lines of demarcation have been fixed to designate the various gradations from high-calcium limestone to pure dolomite.

Dolomite, at best, is a low-priced commodity. Extensive deposits are found in many localities, but for many of its uses it must compete with limestone, which is even more abundant and widely distributed. For some purposes it is even less desirable than limestone, and for those purposes for which its magnesium content is important it meets competition from other sources of magnesium, notably magnesite and natural magnesium salts and bitterns. Even sea water contains magnesium which is occasionally extracted therefrom, but frequently the liquors which remain after common salt (sodium chloride) has been extracted are allowed to go to waste, although they may contain considerable magnesium. In localities remote from manufacturing activity, dolomite deposits must be recognized as having little present commercial value and even in the industrial areas there is nothing that approaches an open market. Consumers, as a rule, either own quarries or have necessarily established contractual relations which guarantee their supplies.

Quarry operations are begun for a variety of reasons and the control of a favorable quarry site is one, and often only a minor factor in the successful establishment of a new enterprise. Before undertaking the working of a dolomite or magnesium limestone deposit the prospective operator should give particular thought to all the economic factors involved, among which may be mentioned (1) Markets and market demands, (2) adequare supply and uniformity of raw material, (3) capital requirements including working capital after the producing stage has been reached, (4) pr duction costs, and (5) possible competition.

DESCRIPTION

Dolomite occurs massive, finely or coarsely granular, or crystallized in small rhombohedral crystals which often have characteristically curved faces. The color varies from white to gray or brown; or more rarely to blue, pink, or yellow. Many magnesium limestones can be distinguished from calcium limestones only by chemical tests. Weathered dolomite is typically chalky white, but variations in magnesium content or impurities may cause differences in color and general appearance.

Composition

The theoretical composition of pure dolomite is 54.3 per cent calcium carbonate ($CaCO_3$), and 45.7 per cent magnesium carbonate ($MgCO_3$). Expressed in another way it contains

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lime (CaO) 30.4 per cent, magnesia (MgO) 21.8 per cent, and carbon dioxide (CO_2) 47.8 per cent.

Magnesium limestones may vary in composition from practically pure $CaCO_3$ with only a few per cent of $MgCO_3$ to a dolomite. Very rarely the percentage of magnesium carbonate is greater than that of a dolomite and may grade to magnesite which, theoretically, is pure $MgCO_3$.

Properties

Dolomite (hardness 3.5 to 4) is slightly harder than calcite but generally softer than fluorite. The specific gravity is 2.8 to 2.9, therefore it is slightly heavier than Calite (specific gravity 2.72). Pure dolomite does not melt; application of sufficient heat drives off carbon dioxide leaving calcium and magnesium oxides. The temperature of this dissociation is about 850°C. or 1,562°F. Crystals of dolomite are pearly or vitreous. If granular, however, the luster is dull or earthy. Dolomite crystals are brittle and break with an uneven to conchoidal fracture. Fragments transmit light poorly or not at all. Certain physical properties such as porosity and crushing strength vary among different deposits.

High-calcium limestones effervesce freely in cold dilute hydrochloric acid, but dolomite and high-magnesium limestones effervesce only if the acid is heated. If polished portions of magnesium limestone are etched by cold weak acid and then examined under a microscope the true dolomite will be unaltered, but the separate calcium carbonate will show surface effects of solution.

THE USES OF DOLOMITE AND HIGH-MAGNESIUM LIMESTONE

Those uses which to a varying degree are dependent upon or affected by the chemical composition of the stone are in (1) refractories, (2) "technical carbonate", (3) certain processes of paper manufacture, (4) some types of lime mortars, (5) blast-furnace flux, (6) Vienna lime, (7) glass works, (8) carbon dioxide and chemicals, (9) agriculture, (10) paints, kalsomine, whitewash, and varnish, (11) ceramics, (12) prepared whiting, (13) rubber preparations, (14) tanneries, (15) fungicides, and (16) such miscellaneous uses as in pig-iron casting, in "pickling" iron and steel, in wire drawing, and in the manufacture of strawboard.

Dolomite, like limestone, may be used as building stone, and as crushed stone, both of which uses, of course, are contingent mainly upon physical properties.

Uses for which Chemical Properties are Important

Refractories

Dolomite and high-magnesium limestone are used extensively as substitutes for magnesite refractories in basic open-hearth steel furnaces and basic Bessemer converters; in lead-refining reverberatory furnaces, lead cupelling furnaces, and crucibles for lead blast furnaces; in copper converters, and copper reverberatory furnaces; and in the form of crucibles for melting metals. Dead-burned material in various forms is commonly used, although raw dolomite may be employed for minor repair work.

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Dead-burned dolomite is made by calcining dolomite or high-magnesium limestone to about 1,500°C. either in a blast furnace or in a special kiln. At this temperature virtually all the CO_2 is driven off, leaving CaO and MgO which sinter to an extent depending upon the impurities present. Many manufacturers add certain agents such as iron oxide, alumina, and silica to the crushed dolomite before calcining, which aids the sintering action. In one process these agents are ground with the dolomite in a wet mill. The slurry is subsequently calcined and clinkered in a rotary kiln similar to that used in the manufacture of cement.

Recently, some dolomite deposits have been found in Missouri which contain the necessary impurities in the right proportion. The use of this stone, dry crushed to granular size and dead-burned, has resulted in a production of a high-grade material, said to be superior to the synthetic mix.

There are two general ways of utilizing dolomite as refractory-masonry work; First, burned dolomite is mixed with tar or a fluxing agent and is applied as a monolithic lining; second, burned dolomite, to which is added tar or suitable fluxing agents, is formed into brick shapes which are fired and then laid in the same manner as other refractory brick.

In steel furnaces the sides and top are usually made of silica brick. Two or three courses of fire brick are laid in the bottom upon the steel shell. There are then added two or more courses of magnesite brick which are stepped up at the sides. The basic bottom is spread directly on the magnesite brick. This material usually is dead-burned grain magnesite sometimes mixed with hot tar or molasses. A binder of 5 to 20 per cent of basic-cinder slag is added. The grain magnesite is fused on in successive layers building up the front and back walls well above the slag line.

Where dead-burned dolomite is used as a substitute for magnesite in such basic bottoms, the raw stone should contain less than 1 per cent of SiO_2, less than 1.5 per cent of combined Al_2O_3 and Fe_2O_3, and at least 35 per cent of $MgCO_3$, the rest being calcium carbonate ($CaCO_3$). Dolomite is somewhat inferior to grain magnesite for this purpose; however, raw or calcined dolomite is satisfactory for minor repair work which requires 40 to 50 pounds or more per ton of steel. The following table compiled by the Bureau of Mines indicates the extent of the dead-burned dolomite industry.

Dead-burned dolomite sold or used by porducers in the United States, 1920-1929

Year	Reported as raw stone		Reported as dead-burned		Total quantity calculated as dead-burned, short tons
	Short tons	Value	Short tons	Value	
1920	612,800	$742,020	316,293	$3,732,522	623,000
1921	79,480	85,786	107,664	1,113,010	147,000
1922	146,640	172,251	348,838	2,813,946	422,200
1923	205,890	249,993	357,642	3,599,116	460,600
1924	309.010	287,137	328,659	3,209,257	483,200
1925	415,710	375,315	392,145	3,730,509	600,000
1926	511,300	458,802	386,715	3,593,731	642,000
1927	434,160	424,140	374,415	3,459,803	591,000
1928	522,850	509,502	448,761	4,283,036	710,000
1929	516,400	461,444	488,032	4,261,942	746,000

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Technical Carbonate

"Technical carbonate" finds its widest utilization in the manufacture of pipe and boiler covering, and for general heat insulation, but it is also used in pharmacy, in the rubber trade, as an accelerator, and as a constituent of certain paints, varnishes, glass, printing inks, cosmetics, table salt, tooth paste, and other commodities. Other names for this material are basic magnesium carbonate, "block magnesia," and magnesia alba. Both in England and in the eastern United States technical carbonate is made chiefly from dolomite by the Pattinson process or a modification thereof. The process of manufacture from dolomite is as follows:

Dolomite mixed with coke is first calcined, thus driving off the carbon dioxide, which is recovered, purified, compressed, and cooled. The calcined rock, essentially a mixture of CaO and MgO, is slaked in water and then recarbonated with the recovered CO_2. In this operation there is made an insoluble calcium carbonate and a soluble bicarbonate of magnesia ($Mg(HCO_3)_2.H_2O$). The calcium carbonate is removed by filtration and the filtrate is boiled, which drives off some of the carbon dioxide and precipitates a white basic magnesium carbonate somewhat variable in composition but considered as having the formula

$4MgCO_3,Mg(OH)_2.5H_2O$.

For the manufacture of the so called "85 per cent magnesia," molded insulation, "technical carbonate" is mixed with asbestos fiber and perhaps other bonding agents, molded into the desired form, dried for 5 or 6 days, and finally cut to true dimension with special machinery.

The following table shows the amount of dolomite used in the manufacture of "technical carbonate."

Dolomite sold or used by producers in the United States for manufacture of basic magnesium Carbonate, 1920-1929

Year	Short tons	Value
1920	57,300	$107,107
1921	32,050	60.648
1922	53,170	79,313
1923	116,410	146,337
1924	98,160	129,390
1925	98,980	131,440
1926	72,850	110,560
1927	69,940	115,932
1928	94,200	122,260
1929	84,750	129,383

Paper Mills

One of the most important methods of making paper from wood is the sulphite process, which is used mainly for the wood of coniferous trees, such as pine, spruce, and hemlock. By digestion in an acid liquor under high temperature and pressure, all the constituents of the wood chips except cellulose are dissolved and removed. This acid liquor is a solution of magnesium and calcium bisulphites, together with more or less free sulphur dioxide, and is obtained by treating either milk of lime or wet limestone with sulphur dioxide, prepared by burning sulphur or iron pyrites in air.

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Dolomitic or high-magnesium lime is preferred for preparing the acid liquor from milk of lime. Magnesium bisulphite is said to be more stable, more soluble, milder, and more effective in its chemical action than calcium bisulphite.[3] Its decomposition products are more soluble and it produces a softer and whiter pulp. Quicklime or hydrated lime used in preparing this liquor should have a minimum of 94 per cent of CaO + MgO, a maximum of 5 to 10 per cent of CO_2, and not more than 3 per cent of Fe_2O_3, Al_2O_3, SiO_2, and insoluble material.

The acid liquor is also prepared by the Jennsen tower system whereby sulphur gases pass up through a tower packed with limestone. There appears to be some objection to using a limestone high in magnesium, because such material is said to break down and clog the tower, thereby hindering gas absorption. According to Claudet[4] a limestone for the tower process should preferably have not more than 2½ per cent of $MgCO_3$, although in some cases 3 per cent may be tolerated and rarely 5 or 10 per cent has been allowed. Other impurities should not amount to more than 2½ per cent, and the $CaCO_3$ content should be at least 95 per cent.

Other requirements for limestone are that it shall be virtually free from mica, pyrite, and graphite or other carbonaceous material, and that when dissolved it will not form a dark scum on the surface of the solution nor form a sludge.

Exact figures on the quantity of high-magnesium lime sold to sulphite paper mills are impossible to obtain as many lime producers who sell burned lime to paper mills do not specify the kind of paper mill, and crude dolomite may be bought by paper mills and calcined at the mill. The following figures are an estimate of the quantity and value of high-magnesium lime sold to sulphite paper mills from 1920 to 1929.

High-magnesium lime sold by porducers in the United States to sulphite paper mills, 1920-1929

Year	Short tons	Value
1920	121,817	$1,347,321
1921	68,992	711,345
1922	70,000	650,000
1923	75,000	750,000
1924	70,000	625,000
1925	53,000	451,000
1926	52,600	482,000
1927	50,000	441,000
1928	46,000	359,000
1929	51,000	398,000

Lime Mortars and Plasters

Lime manufacture consists essentially in the calcination of high-grade limestone, dolomites, or rocks of intermediate composition. High-magnesium limestones and dolomites

3 National Lime Association, Lime - Its Use and Value in the Industrial Chemical Processes: Washington, D. C., 1930, 88 pp.

4 Claudet, H. H., Limestone for Pulp and Paper Industry: Canadian Min. Jour., vol. 49, April 13, 1928, p. 306.

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are used extensively for making lime. The limes of northern Ohio, the most productive lime-burning area in the United States, are nearly all manufactured from a practically pure dolomite.

Lime mortars are used mainly as bonding agents for brick and masonry work, and lime finds extensive utilization in plaster and various synthetic building materials. Such mortar essentially is a mixture of well-slaked lime, sand, and water, to which may be added Portland cement.

The reactions of dolomitic lime and calcium lime differ somewhat in the slaking process. A high-calcium lime expands greatly when water is added and much heat is liberated Such mortars, however, are apt to be short or relatively nonplastic. Dolomitic lime slakes much more slowly, generates less heat, and the expansion in volume is less, which makes a correspondingly smaller yield. As a rule the dolomitic mortars are more plastic and therefore have a greater sand-carrying capacity. The choice of mortars is often determined by the experience of an individual mason or contractor. Dolomitic-lime mortars have a higher ultimate strength, but this factor need seldom be considered in the selection of a mortar. The chief use of high-magnesium lime is as a finishing-coat plaster, for which it is very popular because of its high plasticity.

Blast Furnace Flux

Cost is the principal factor in the utilization of limestone as a flux in metallurgical operations. This is particularly true in the pig-iron industry where large quantities of limestone must be used in the reduction of iron ore. Most furnace operators use the cheapest form of limestone available and the chemical composition, within certain limits, generally is of secondary importance. In smelting iron ores in blast furnaces the impurities are mainly silica and alumina, and in order to remove those as slag, a basic flux must be added. At the fusion zone about 15 per cent of the original iron is still in the form of unreduced oxide, and if insufficient flux is employed, some of this iron is lost in the slag. The flux also takes care of the ash left from the combustion of coke, and aids in removing sulphur and other impurities. Dolomite is preferred in the manufacture of ferrosilicon and ferromanganese, because it fluxes off very little of the silica or manganese.

The magnesia content of the slag has an effect upon the subsequent use of such material. Some operators prefer 7 to 10 per cent of magnesia in slag when it is used for road purposes. The magnesia content, however, is objectionable in any slag which is to be used in the manufacture of cement.

The effect of magnesia on the fluxing action is a question that has received much discussion. In some instances dolomite and high-magnesium limestone appear to increase the viscosity of the slag, whereas in other cases quite opposite results have been obtained.

Miscellaneous

Glass Works.- Limestone is used in the glass industry as a flux, generally as ground limestone or more rarely as an oxide or hydrate. Magnesium in limestone makes glass somewhat more difficult to melt but sometimes is desired in making certain forms of optical glass. Limestone high in magnesium is said to be preferred where certain types of automatic machinery are employed. Glass manufacturers require a limestone of uniform grade because

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of the rigid control necessary in handling flux batches. Therefore, either a high-calcium or a dolomitic limestone is preferred because of the greater consistency in chemical composition of these two kinds of material.

Carbon Dioxide and Chemicals.- A few years ago, according to reports of sales received by the United States Bureau of Mines, crude dolomite aggregating about 35,000 ton and valued at more than $60,000 was used annually in the manufacture of carbon dioxide. Figures since 1926 can not be published because only two operators reported production of dolomite for this purpose. Carbon dioxide is used in the manufacture of beverages and in chemical plants such as those producing epsom salts (magnesium sulphate).

Several process have been pattented for producing various magnesium chemicals from dolomite, including magnesium chloride for use in the manufacture of magnesium metal; but except for plants utilizing carbon dioxide locally, other sources of magnesium, either magnesite or natural salt deposits and brines, are generally considered more economical. Projects utilizing dolomite for the manufacture of Sorel or magnesium oxychloride cements have likewise been doomed to failure unless the raw material so used contained a substantial admixture of magnesite. The amount of dolomite used in the manufacture of carbon dioxide is shown in the following table.

Dolomite sold by producers in the United States for the manufacture of carbon dioxide, 1920-1929

Year	Short tons	Value
1920	33,040	$73,671
1921	34,090	124,984
1922	38,280	58,748
1923	38,460	52,494
1924	34,300	57,105
1925	19,740	36,854
1926	16,520	31,424
1927	(a)	(a)
1928	(a)	(a)
1929	(a)	(a)

(a) Bureau of Mines not at liberty to publish figures.

Agriculture.- Limestone finds wide employment as a soil conditioner and fertilizer. It not only corrects acidity and supplies a valuable plant food but may also add to the porosity of the soil, thereby aiding in proper drainage. For these purposes ground limestone or hydrated lime may be used, and in some instances calcium oxide or quicklime is put on the soil. Opinions differ as to the effect of magnesium compounds, but both magnesium and calcium limestones are used successfully.

Paints, Kalsomine, Whitewash, and Varnishes.- Finely pulverized limestone and marble flour are used to a considerable extent as paint fillers. Lime is employed in the preparation of resins used in the manufacture of varnish, and hydrated lime is used for kalsomines and whitewash. The relative amounts of calcium and magnesium carbonate are immaterial for most of these uses.

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Vienna Lime.- Vienna lime is made from high-magnesium limestone or dolomite, analyzing about 55 per cent of $CaCO_3$, and 43 per cent of $MgCO_3$ with traces of iron, silica, and alumina. The rock is greayish white, fine-grained, and contains certain characteristic fossils (gastropods) which are said to affect materially its qualities. The stone is carefully calcined by a secret process, and the lime is cleaned, ground, packed in sealed containers, and sold to manufacturers of buffing compounds.

Vienna lime is used for buffing nickel, brass, copper, pearl, celluloid, and other metal and manufactured articles. It is softer than silica, but generally harder than the artificially prepared metallic oxides such as crocus, red, green, and black rouges. Eardley-Wilmot[5] states that:

> The most important use is for nickel and the lime is now recognized as the standard composition for the "coloring" of nickel after plating, as it gives it a deep "under surface" blue peculiar to the metal. Vienna lime cuts faster than crocus and has almost entirely replaced it for all classes of work. Vienna lime should not be used on aluminum as it attacks it chemically.
>
> The action of Vienna lime in buffing is not clearly known, but it is believed that the heat generated on the buff causes a caustic action due mainly to the lime, and the magnesia does the work as it helps to drag and create the necessary friction, but excess of lime would cause it to slip too readily. As soon as the lime becomes hydrated it ceases to function and also attacks the grease compositions.

Ceramics.- Limestone is used to a certain extent in the manufacture of pottery and porcelain ware. It is used in the form of a carbonate as a levigated natural whiting, as a hydrate, or as an oxide. Its function is to aid in fluxing the various materials and for some purposes a relatively high-magnesia content is preferable. In other cases a high-calcium content is desired.

Prepared Whiting.- Magnesium lime is used in preparing a very fine-grained pigment for coating paper. The iron content must be very low, as a pure white color is demanded. This pigment is made by adding sodium carbonate to a suspension of freshly slaked magnesium lime.

Rubber.- Dolomite or high-magnesium limes are used as hardening agents in the manufacture of soft-rubber goods. High-calcium limes have a similar application in making hard-rubber products. Both kinds of lime are also used to some extent as accelerators in the vulcanizing process.

Tanneries.- At the depilatory stage of leather tanning, lime is used extensively. Ordinarily, any magnesium oxide present is objectionable because it tends to give a "harsh" or "rough" leather. In the manufacture of morocco leather, however, magnesium lime is preferred.

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5 Eardley-Wilmot, V. L., Abrasives, Part I: Siliceous Abrasives: Canada Dept. Mines Branch 673, 1927, p. 97.

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Fungicides.- Either a magnesium or calcium-lime hydrate may be used in preparing dry-mix sulphur-lime which is used as a fungicide.

Minor Uses.- Other minor uses include the employment of a limited amount of hydrated lime in pig-iron casting, in "pickling" iron and steel, and in wire-drawing. Some is also used in the manufacture of strawboard. Either a magnesium or a calcium lime may be used.

Uses for Which Physical Properties are Important

Building Stone

Requirements of building stone depend principally upon physical rather than chemical properties. Usually any limestone which has the right physical characteristics such as homogeneity of structure, high density, low porosity, and pleasing color will serve as a good building stone, irrespective of the percentage of magnesium carbonate which it contains. It is held, however, by some authorities that a true dolomite is better than a so-called magnesium limestone because of the slight difference in solubility between calcium carbonate and magnesium carbonate. Sulphurous gases in the atmosphere may cause crystals of calcium sulphate and magnesium sulphate to form which are apt to grow and disrupt the stone. Many deposits consisting of alternate layers of calcite and dolomite do not yield rock satisfactory for building material. The governing factor here seems to be again one of homogeneity.

Many commercial marbles contain varying amounts of magnesium carbonate and some are nearly pure dolomite.

Crushed Stone

The enormous amounts of crushed stone used annually for concrete aggregate, road stone, and railroad ballast make this market outlet one of the most important. Here again physical characteristics are paramount and little attention need by paid to the chemical composition except in so far as experience may prove in a given locality or deposit that a different chemical composition indicates a corresponding difference in physical characteristics. Where this is the case it logically follows that close attention must be paid to any variations in chemical composition. With crushed stone, too, because of its relatively low price, other factors such as availability and proximity to markets are usually more important.

Coal-Mine Dusting

To decrease the hazard of dust explosions in coal mines, finely-ground limestone may be liberally applied to the walls, floors, and roofs of the various entries and rooms. For this purpose the chemical content is immaterial, and either a magnesium or calcium limestone may be used.

Asphalt Filler

Asphalt used for paving and roofing consumes a relatively large quantity of finely pulverized limestone. For this market the physical characteristics are important and particular consideration is given to grinding and sizing. Owing to this added cost of

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manufacture, the material commands a somewhat higher price and therefore may be transported to a considerable distance for use. Either a magnesium or calcium limestone may be used.

Miscellaneous Uses

Minor uses of limestone, the requirements of which are similar to those of building stone, include stone used for curbing, flagging, paving, rubble, riprap, roofing gravel, stucco, terrazzo, and artificial stone.

Other minor uses are for filter beds, poultry grit, and lithographic stone of which the German variety is a fine-grained magnesium limestone.

Uses of Limestone for Which Magnesium Carbonate is Usually Objectionable

To outline more clearly the field of usefulness of dolomite and magnesium limestone, the following uses for which a high-calcium limestone is essential or preferred are mentioned.

Portland Cement and Natural Cement

Limestone is one of the major raw materials used in the manufacture of Portland and natural cements. Such stone, however, must be low in magnesium content, the usual tolerance being about 5 per cent of MgO.

Water Purification

Much of the water used for domestic and industrial purposes is treated to remove calcium or magnesium carbonate that has been dissolved and held in solution by carbon dioxide absorbed from the atmosphere. Lime added to the water combines chemically with the excess carbon dioxide, forming calcium carbonate, which together with the calcium carbonate previously held in solution is thereby precipitated and subsequently removed by filtration or by decantation. A high-calcium lime generally is preferred for treating water and may be used either as quicklime or as hydrated lime.

Sand-Lime Brick

Sand-lime bricks are made by mixing sand with a small percentage of hydrated lime (usually about 8 per cent) and then molding to form in heavy presses. Subsequently the bricks are allowed to harden under steam pressure. This results in brick consisting essentially of sand which is cemented together by calcium silicate. For this purpose the lime used must be very low in magnesium.

Silica Brick

Silica brick which is used for a refractory in furnace linings differs from sand-lime brick in the curing process. Silica bricks consist of silica bonded with hydrated lime, after which the mixture is molded, carefully dried, and then burned in a special type of kiln. For this purpose the lime should have at least 92 per cent available calcium oxide and not more than 3 per cent available magnesium oxide.

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Alkali Works

Limestone is used extensively as a reagent in alkali works, particularly in the manufacture of soda ash and caustic soda. A high-calcium limestone is commonly employed.

Calcium-Carbide Works

In the manufacture of calcium carbide, limestone is calcined and melted in an electric furnace with carbon in the form of coke, charcoal, or coal. A high-calcium limestone must be used because magnesium is objectionable. The usual requirements are that the stone shall have less than 2 per cent of MgO, 0.01 per cent of phosphorous, and 3 per cent of silica.

Sugar Refineries

Lime is used extensively in the refining of sugar. Magnesia is objectionable and only high-calcium limes are employed. Sugar refiners may purchase raw limestone and burn their own lime. Such stone should contain less than 1 per cent of silica and less than 1 per cent of magnesia.

Cyanide Process

In the recovery of gold and silver by the cyanide process quicklime or milk of lime is added to impart what is known as "protective alkalinity." Experiments with dolomite have shown that the latter should not be substituted for this purpose.

Basic Open-Hearth Steel Flux

A limestone flux varying from 6 to 12 per cent of the basic open-hearth furnace charge is added mainly for the removal of phosphorus and sulphur. As magnesium is a poor phosphorous remover, the maximum permissible content of MgO is usually fixed at 5 per cent.

ORIGIN AND OCCURRENCE

The genesis of dolomites is not thoroughly understood. Some are thought to be of marine origin, formed either directly from magnesium and calcium salts in the sea water, or by a subsequent magnesium enrichment of calcium carbonate already deposited from the ocean by organisms.

Some magnesium limestones and dolomites, however, are of other than marine origin. In certain localities, beds of calcium limestone alternate with strata of limestone containing a greater or lesser percentage of magnesium carbonate. Analyses of a single limestone bed, too, may vary over a relatively small area. The formation of such deposits would indicate that the magnesium carbonate is concentrated either by the leaching away of the more easily dissolved calcium carbonate or by a direct deposition of magnesium carbonate from circulating ground waters; in fact, both processes doubtless have effected changes in some instances.

The concensus of opinion seems to be that most dolomites and magnesium limestones were not originally deposited as such, but that dolomitization resulted from changes subsequent to deposition, mainly by the action of magnesium salts in sea water.

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Dolomite and magnesium limestones are widely distributed over the world. In some localities deposits attain enormous proportions, as in the Dolomite Alps of Europe. Many occurrences are associated with calcium limestones, but only few with magnesite. Deposits may be evenly bedded or may be greatly deformed and some have become metamorphosed to dolomitic marbles. Examples of this type are found in Vermont, Massachusetts, New York, Georgia, and Tennessee. Because of the wide distribution of dolomite and magnesium limestone in the United States no attempt can be made here to list such occurrences.

METHODS OF PRODUCTION

The mining or quarrying of dolomite does not differ essentially from that of limestone, and the methods employed for preparing it for market are likewise the same as for limestone and need not be described in this paper. In calcining, however, the presence of magnesium carbonate introduces some special problems. The best grade of lime is produced when the temperature is held as closely as possible to the point where the carbon dioxide is given off freely. For pure limestone this reaction begins at about 900°C. and the heat may be safely carried to 1,200°C. Over-burning is caused by too high a temperature and the resulting product may be dense and discolored, and much more difficult or even impossible to slake. Since the decomposition temperature of magnesium carbonate is about 750°C. and that for dolomite about 850°C., it follows that temperatures which may be safe for burning a high-calcium limestone may overburn the magnesium carbonate and, conversely, temperatures sufficient to calcine the magnesium carbonate or dolomite may leave the calcium carbonate in the raw state.

STATISTICS OF PRODUCTION

Complete production figures for dolomite and magnesium limestone are not available because of the difficulty in segregating them from the total production figures for limestone and lime of all kinds. Production figures are available, however, for crude dolomite used as dead-burned dolomite for refractories, basic magnesium carbonate, sulphite process of paper manufacture, and a certain amount of dolomite which is calcined merely for its CO_2 content. The available statistics which have been compiled by A. T. Coons of the United States Bureau of Mines have already been listed under the respective uses.

Production statistics of limestone and lime are to be found in other publications of this bureau.

MARKET PRICES

The ultimate value of dolomite and magnesium limestones depends mainly upon the extent of preparation for market. Because limestone is widely distributed and is very abundant, it commands a relatively low price, but quarrying, crushing, sizing, burning, and hydrating add proportionately to the cost of the finished product. The market value of such material therefore depends mainly upon the expense of manufacture. Another factor influencing price is the location. Owing to natural conditions some localities are able to produce limestone products at a lower unit cost than others. Transportation of the material is also an important factor in the ultimate value. Where limestone products have to be transported any appreciable distance the freight charges in many cases are larger than the original cost of the material. Production statistics yield an approximation of the unit value of dolomite and high-magnesium lime. It will be noted that raw stone sold by producers for dead-burned

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dolomite in 1929 was valued at less than $1 per ton. Dead-burned material for that year had an approximate unit price of about $8.75 per ton. The dolomite sold or used by producers for manufacture of basic magnesium carbonate had a unit value in 1929 of about $1.50 per ton.

High-magnesium lime sold for use in sulphite paper mills in 1929 had a unit value of about $7.80. It must be understood that these prices are very general and do not apply o any one particular operation or locality but are the average of all stone reported to the bureau for the uses described.

The following prices of limestone as quoted in Rock Products of May 9, 1931, may be indicative of potential markets for dolomite:

Crushed limestone, 30 cents to $2.25, depending upon the location and grade.
Agricultural limestone, 75 cents to $6, depending upon source, purity, fineness, method of packing, and whether crushed or pulverized.
Pulverized limestone for coal operators, $2.25 to $6, depending upon locality and grade.
Lime products.- Hydrated lime, $6 to $20.
Ground burnt lime, $6 to $17.50.
Lump lime, $4.50 to $20.
Terrazzo and stucco chips, $9.80 to $13.80.
Chicken grits, 90 cent to $10.

The foregoing prices are per short ton f.o.b. shipping point and depend to a considerable extent upon grade, locality, and method of packing.

IMPORTS AND DUTIES

Dolomite is not specifically mentioned in the tariff act of 1930. Imported for use as monumental or building stone it is dutiable at 15 cents per cubic foot if not dressed, hewn, or polished, and at 50 per cent ad valorem if manufactured (par. 234-c). Dead-burned dolomite, if imported, would doubtless fall within the blanket classification for earthy or mineral substances under paragraph 214, dutiable at 30 per cent on its foreign market value.

Import statistics of dolomite and dolomite products are not available, but in general the international trade on these low-priced commodities is relatively small.

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